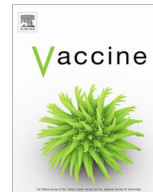




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Education level modifies parental hesitancy about COVID-19 vaccinations for their children



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ABSTRACT

It is important to encourage parental acceptance of children's vaccination against COVID-19 to ensure population immunity and mitigate morbidity and mortality. This study drew upon protection motivation theory (PMT) to explore the factors of parental hesitancy about vaccinating their children. A national online survey was performed in China. A total of 2054 Chinese parents of children aged 6–12 years were included in this study. They reported on measures that assessed hesitancy about children's vaccination against COVID-19, PMT constructs (susceptibility, severity, response efficacy, self-efficacy, and response costs) and sociodemographic characteristics. Chinese parents reported a hesitancy rate of 29.4% for children's vaccination. Parents with higher level education were more likely to hesitate to vaccinate their children against COVID-19. After controlling for parents' and children's demographic variables, logistic regression showed that parents' hesitancy about their children's vaccination increased if parents had lower levels of susceptibility, response efficacy or self-efficacy, as well as higher levels of response costs. In addition, a high educational level can significantly increase the promotive effect of response cost and the protective effect of response efficacy on vaccine hesitancy. In conclusion, our findings suggested that PMT can explain parents' vaccine hesitancy and that education level can modify the effect of copying appraisal, but not threat appraisal, on parental hesitancy. This study will help public health officials send targeted messages to parents to improve the rate of COVID-19 vaccination in children aged 6–12 years and thus reach a higher level of immunity in the population.

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1. Introduction

The COVID-19 pandemic has caused >638 million infections and >6.5 million deaths as of Nov 2022. The disease affects large numbers of people of all age groups worldwide. Vaccination is one of the most cost-effective public health intervention strategies in limiting the spread of the infectious disease [1,2]. It is important for government and public health officials to encourage acceptance and uptake of the vaccine to ensure population immunity and mitigation of morbidity and mortality. In this context, after the COVID-19 vaccine was approved for use in children, overcoming barriers to vaccinating children became crucial.

Vaccination reduces infection risk of infectious disease in healthy children from 30% to 11% [3] and controls virus transmis-

sion [4,5]. With the emergence of new variants, the risk of disease transmission and outcomes in children requires close surveillance [6,7]. Despite the importance of vaccination, in our previous study, the prevalence of vaccine hesitancy in Chinese adults was 44.3% after the emergency use authorization of COVID-19 vaccine for adults [8]. Vaccine hesitancy refers to a delay in the acceptance or refusal of vaccination despite adequate access and availability [9]. Since parents are often key decision-makers for whether their children will receive vaccinations, it is important to measure vaccine confidence among parents of young children and to investigate the factors of parental hesitancy about children's vaccination.

In this study, parental hesitancy about vaccinating children can be regarded as a health-related behaviour. People usually use information to evaluate the threat of diseases and the efficacy of responses before making behavioural decisions and taking action. Protection motivation theory (PMT) is an important theoretical framework to predict an individual's health behaviour, including threat appraisal and coping appraisal. Threat appraisal includes perceived susceptibility and perceived severity of the threat [10]. The coping appraisal process includes efficacy appraisal (response

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efficacy and self-efficacy) and response costs [11]. The hypothesis of this theory is that a high threat appraisal and high efficacy appraisal will increase the probability of health action and reduce the probability of undesirable behaviour, while a high response cost will reduce the probability of health behaviour. The PMT constructs have been successfully applied to understand and predict changes in the health behaviours associated with severe acute respiratory syndrome (SARS) [12], influenza A H1N1 [13,14], hepatitis B [15] and COVID-19 [16]. In the context of parental hesitancy about vaccinating their children, susceptibility refers to parents' perception of whether their children are vulnerable to COVID-19 infection, and severity refers to the damage that COVID-19 may cause to their children's health. Response efficacy is the belief that the COVID-19 vaccine will be beneficial to their children. Self-efficacy is the belief that parents themselves have the ability to have their children vaccinated. Response costs refer to the ineffectiveness and the side effects of the COVID-19 vaccine, such as pain and swelling of the injection site and headache.

PMT is an important theoretical framework to explain parental hesitancy about vaccinating their children. Previous studies have used the Health Belief Model (HBM) and Theory of Planned Behavior (TPB) to explain parents' COVID-19 vaccine hesitancy or intention [17], but with no relevant evidence for PMT. In addition, some demographic factors were found to be associated with vaccine hesitancy and may influence their threat appraisal and coping appraisal [18–20]. This study, conducted during a period in which COVID-19 vaccines were not authorized for nationwide use in children aged 6–12 in China, examined the factors related to parents' hesitancy based on the PMT model and explored the influence of key demographic factors on the effect of the PMT construct on parental hesitancy about children's COVID-19 vaccination. This study will help public health officials send targeted messages to parents to improve the COVID-19 vaccination rate in children aged 6–12 years and thus reach a higher level of immunity in the population.

2. Method

2.1. Participants and procedures

A cross-sectional, anonymous online survey was performed among Chinese residents. The survey was made available on the Wenjuanxing platform from October 19 to October 28, 2021, the period in which COVID-19 vaccines were not yet authorized for nationwide use in children aged 6–12 in China. Parents who had children aged 6–12 were invited to participate in the survey. If the parents had more than one eligible child, information was requested for the child whose birthday was closest to the survey date, to avoid confusion and inconsistency on the survey. A convenience sampling strategy was utilized. The online questionnaire link was disseminated via websites and WeChat, which were public websites that could be shared with family members, friends, and colleagues and forwarded to others. In addition, the online questionnaire link was sent to several primary schools that cooperated with us, including four schools in North China and two schools in South China. These schools were invited to share the questionnaire link with the parents of their students. Informed consent was provided on the first page of the survey. The survey took approximately 3–5 min on average, and questionnaires that were completed in <100 s were considered invalid, reflecting a careless response. A quality control item with a required answer was also set to avoid the return of invalid questionnaires. Prior approval by the Human Research Ethics Committee at Fudan University was obtained.

2.2. Measures

The questionnaires requested sociodemographic characteristics of parents and their children, parental hesitancy about vaccinating their children against COVID-19, and PMT constructs.

Outcome measures: Parental hesitancy about vaccinating their children against COVID-19 was measured with a single item, “How willing would you be to vaccinate your child aged 6–12 y against COVID-19?”, which was measured on a seven-point scale (from “1 = refuse all” to “7 = accept all”). In this study, parental hesitancy about vaccinating their children was regarded as any response on the scale except for “accept all” or “accept but unsure”.

Sociodemographic characteristics: This study recorded the sociodemographic characteristics of parents (e.g., age, gender, region, marital status, educational level, occupation and annual family income per capita) and children's gender. In addition, participants were asked to rate their children's overall health on five semantic differential scales (from “1 = very good” to “5 = bad”). Participants with answers of “very good” and “good” were categorized as overall “healthy”. Proportion of COVID-19 vaccination among family members over 12 years old was assessed on five semantic differential scales (from “1 = all” to “5 = no one”).

PMT constructs: Five PMT constructs, namely, susceptibility, severity, response efficacy, response cost, and self-efficacy, were each measured using several self-devised items. A five-point Likert scale was used to measure all of the items related to the PMT constructs, with a range from “1 = strongly disagree” to “5 = strongly agree”. The questions related to PMT constructs as well as the reliability and validity evaluation results of the questionnaire are shown in Table 1. The Cronbach's alpha was above 0.800, indicating good reliability. The factor loading of most questions was higher than 0.700, and the validity of the questions was good. The KMO value was equal to 0.892, and the structural validity of the questionnaire was good.

2.3. Statistical analyses

First, the frequencies and proportions were calculated for the sociodemographic characteristics to capture the tendencies of parental hesitancy about vaccinating their children. Only significant sociodemographic factors, with p values of <0.05, were selected for the subsequent multivariate logistic regression analysis. Second, Kaiser–Meyer–Olkin (KMO) was calculated to assess validity and overall construct validity for each question. The factor loading of each item in PMT was assessed by using exploratory factor analysis (EFA). EFA utilized a principal component analysis framework with varimax rotation, which was conducted for each item in PMT, using Cronbach's alpha to estimate the internal reliability of the items for PMT construct measures. The median scores of the five constructs in PMT were calculated separately. If the score was less than the median, it was defined as “low level”; otherwise, it was defined as “high level” and converted to binary variables. Next, logistic regression analyses were applied to identify the predictors of parental hesitancy based on PMT constructs, adjusting for age, education level, occupation, annual family income per capita, parent-rated children's health, proportion of vaccinated family members, and PMT constructs. Odds ratios (ORs) and 95% confidence intervals (95% CIs) were used to quantify the effects. Finally, Pearson's bivariate correlations and Cochran–Mantel–Haenszel (CMH) analysis were applied to study the correlation between PMT and vaccine hesitancy after considering the modification effect of educational level. All analyses were carried out using SPSS 25.0. All tests were two-tailed with a significance level of $P < 0.05$.

Table 1

Items used to assess the constructs and the factor analysis results of the PMT factors of COVID-19 vaccine hesitancy.

Constructs	Assignment and Variable Processing	Questions	Factor Loading	Cronbach's α
Perceived susceptibility	1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree. The median of respondents' averaged index (median = 3.00) was used for binary categorical classification (high/low level).	a. I think my children are more likely to be infected with the COVID-19 virus.	0.827	0.814
		b. I think COVID-19 infection is likely in children 6–12 years old because of a lack of health consciousness and protective behaviour.	0.666	0.808
Perceived severity	1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree. The median of respondents' averaged index (median = 5.00) was used for binary categorical classification (high/low level).	a. If the child is infected with COVID-19, it will have a serious impact on the family.	0.866	0.801
		b. If the child is infected with COVID-19, it will have a serious impact on the child's school and life.	0.867	0.801
		c. If a child is infected with COVID-19, there is a risk of severe illness.	0.800	0.801
		d. Infection with the novel coronavirus pneumonia is harmful to children's health.	0.756	0.804
Response efficacy	1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree. The median of respondents' averaged index (median = 4.33) was used for binary categorical classification (high/low level).	a. The COVID-19 vaccine for children helps to establish a universal immune barrier.	0.668	0.803
		b. Vaccine can effectively prevent COVID-19 infection.	0.585	0.805
		c. After children are vaccinated for COVID-19, their daily lives and travel will be more convenient.	0.581	0.804
Response cost	1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree. The median of respondents' averaged index (median = 3.00) was used for binary categorical classification (high/low level).	a. I am worried about COVID-19 vaccine adverse reactions.	0.836	0.814
		b. I am worried about the long-term adverse effects of the vaccine on the body.	0.807	0.811
		c. I'm worried that the effective time of prevention is not long enough.	0.768	0.807
		d. If children receive the COVID-19 vaccine, the adverse reactions could be serious.	0.758	0.814
		e. I think the vaccine is not effective in preventing COVID-19.	0.768	0.820
		f. I don't think the COVID-19 vaccine can protect against a mutant strain.	0.738	0.819
Self-efficacy	1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree. The median of respondents' averaged index (median = 3.50) was used for binary categorical classification (high/low level).	a. Even if there are adverse reactions, I believe it will not cause long-term damage to health.	0.755	0.811
		b. If adverse reactions occur after vaccination, I believe they can be handled in time.	0.803	0.806
		c. I think the possibility of adverse reactions after vaccination is low.	0.790	0.806
		d. If I want to vaccinate my child, I know where and how to get vaccinated successfully.	0.697	0.808

3. Results

3.1. Sociodemographic characteristics

A total of 2199 participants from 29 provinces and autonomous regions (China consists of a total of 34 provinces and autonomous regions) completed the survey. A total of 145 questionnaires were excluded from the analysis due to the following exclusion criteria: (1) children with contraindications to vaccines ($n = 47$), (2) participants who answered quality control questions incorrectly ($n = 75$), (3) participants who were abroad ($n = 3$), (4) participants whose completion time was <100 s ($n = 13$), and (5) participants who have the same answer to all questions ($n = 7$). Finally, 2054 (93.4%) valid questionnaires were included in the following analyses.

As shown in Table 2, the results of descriptive analyses showed that participants reported a hesitancy rate of 29.4% ($n = 603$). Most respondents were 31–40 years old (60.4%), women (70.4%). In a multivariate logistic regression analysis, the factors associated with hesitancy to vaccinate children were parents who had a bachelor's degree or above, front-line workers in health care, had a family income per capita of more than ¥120,000, had a lower proportion of vaccinated family members, or rated their children's health as poor ($P < 0.05$). Parents over 40 years old were less likely to be hesitant to vaccinate their children ($P < 0.05$).

3.2. Predictors of parents' hesitancy about children's vaccination based on PMT constructs and vaccination experiences

Logistic regressions were run with “vaccine hesitant” or “non-vaccine hesitant” as the outcome to explore the predictors of parents' hesitancy. Adjusted variables in parental hesitancy logistic regression included age, education level, occupation, family income per capita, parent-rated children's health, proportion of vaccinated family members, and each PMT construct. As shown in Table 3, a high level of perceived susceptibility, response efficacy and self-efficacy ($P < 0.001$) significantly decreased parents' hesitancy about vaccinating their children. However, parents with a high level of response cost were three times more likely to be hesitant about vaccinating their children than those with a low level of response cost ($P < 0.001$).

3.3. Association between PMT constructs and parental hesitancy among different education attainment layers

Considering that education level is a significant demographic predictor for parental hesitancy, we further explored the influence of level of education on the association between PMT constructs and parental hesitancy. Table 4 presents the correlations between COVID-19 vaccine hesitancy and parents' education level and each PMT construct. A high education level was related to a low level of

Table 2
Distribution of vaccine hesitancy by participant demographics and health-related characteristics.

Demographics	Overall (n = 2054) n (%)	Vaccine hesitancy rate (n = 603, 29.4 %) n (%)	^a OR (95%CI)	P value
<i>Parents' information</i>				
Age (years)				
<30	385 (18.7)	117 (30.4)	1	
31–40	1240 (60.4)	375 (30.2)	0.83 (0.63, 1.08)	0.160
>40	429 (20.9)	111 (25.9)	0.71 (0.51, 0.99)	0.042
Gender				
Men	607 (29.6)	165 (27.2)	1	
Women	1447 (70.4)	438 (30.3)	1.04 (0.83, 1.30)	0.743
Ethnic				
Han	1927 (93.8)	572 (29.7)	1	
Other	127 (6.2)	31 (24.4)	0.86 (0.55, 1.35)	0.522
Marital status				
Married	1892 (92.1)	563 (29.8)	1	
Not married	162 (7.9)	40 (24.7)	0.85 (0.58, 1.26)	0.427
Region				
Urban	1357 (66.1)	426 (31.4)	1	
Town	492 (23.0)	129 (26.2)	0.98 (0.76, 1.26)	0.876
Rural	205 (10.0)	48 (23.4)	0.91 (0.62, 1.31)	0.601
Educational level				
Middle school degree and below	722 (35.2)	156 (21.6)	1	
High school degree	602 (29.3)	153 (25.4)	1.23 (0.94, 1.61)	0.135
Bachelor degree and above	730 (35.5)	294 (40.3)	1.98 (1.48, 2.64)	<0.001
Risk of infection in occupation				
High risk	188 (9.2)	58 (30.9)	1	
Low risk	1866 (90.8)	545 (29.2)	1.14 (0.78, 1.64)	0.504
Occupation				
Non-medical related workers	1908 (92.9)	543 (28.5)	1	
Front-line workers in health care	64 (3.1)	32 (50.0)	2.20 (1.25, 3.88)	0.006
Other relevant workers in health care	82 (4.0)	28 (34.1)	1.05 (0.64, 1.75)	0.839
Family income per capita (RMB)				
<30,000	662 (32.2)	158 (23.9)	1	
30,000–59,999	503 (24.5)	122 (24.3)	0.87 (0.65, 1.16)	0.346
60,000–120,000	480 (23.4)	143 (29.8)	1.02 (0.77, 1.37)	0.872
>120,000	409 (19.9)	180 (44.0)	1.48 (1.07, 2.06)	0.02
Proportion of COVID –19 vaccination among family members > 12 years old				
All	1739 (84.7)	469 (27.0)	1	
Most	201 (9.8)	85 (42.3)	1.78 (1.30, 2.43)	<0.001
Half and below	114 (5.5)	49 (43.0)	1.97 (1.31, 2.95)	0.001
<i>Children's information</i>				
Gender				
Men	1112 (54.1)	316 (28.4)	1	
Women	942 (45.9)	287 (30.5)	1.08 (0.88, 1.32)	0.463
Parents' self-assessment of children's overall health				
Health	1953 (95.1)	551 (28.2)	1	
Poor/bad	101 (4.9)	52 (51.5)	2.86 (1.87, 4.36)	<0.001

^a OR: odds ratio.

response efficacy and self-efficacy and a high level of response cost. As shown in Fig. 1 and Supplementary Table 1, the impact of education level on the relationship between response cost and parental hesitancy ($P = 0.001$), as well as between response efficacy and parental hesitancy ($P = 0.010$), is different. As parents' education level increased, their response cost played a greater role in promoting parental hesitancy (Fig. 1 A, Supplementary Table 1) with an OR of 1.87 (95% CI 1.30–2.68) for individuals with a middle school education or less, an OR of 3.54 (95% CI 2.34–5.35) for those with a high school diploma, and an OR of 5.05 (95% CI 3.52–7.23) for those with a bachelor's degree or more. With the increase in parents' education level, their response efficacy will have a less inhibitory effect on parental hesitancy (Fig. 1 B, Supplementary Table 1), with an OR of 0.22 (95% CI 0.15–0.32) in the middle school education or less group, an OR of 0.10 (95% CI 0.07–0.16) in the high school diploma group, and an OR of 0.10 (95% CI 0.06–0.15) in the bachelor's degree or more group. However, the impact of

self-efficacy on parental hesitancy between education levels was homogeneous ($P > 0.05$, Supplementary Table 1). These findings suggest that education levels modify the impact of coping appraisal (response cost and response efficacy) on parental hesitancy.

4. Discussion

Our findings indicate that a high education level and family income, a low proportion of COVID-19 among family members, and parent-assessment of their children's poor health were associated with high vaccine hesitancy. Furthermore, a low level of perceived susceptibility, response efficacy and self-efficacy and a high level of response cost were associated with high COVID-19 vaccine hesitancy. Moreover, education levels modified the impact of response cost and response efficacy on parental hesitancy.

Although there are many studies on parents' attitudes towards childhood vaccination [21,22], we first reported that education

Table 3
Logistic regression analysis of PMT constructs.

Constructs	Vaccine hesitancy n (%)	^a OR (95%CI)	P value
<i>Perceived susceptibility</i>			
Low	310 (43.2)	1.00	
High	293 (21.9)	0.55 (0.43, 0.69)	<0.001
<i>Perceived severity</i>			
Low	399 (39.2)	1.00	
High	204 (19.7)	0.84 (0.65, 1.08)	0.180
<i>Response efficacy</i>			
Low	481 (50.2)	1.00	
High	122 (11.1)	0.25 (0.19, 0.33)	<0.001
<i>Self-efficacy</i>			
Low	404 (43.3)	1.00	
High	199 (17.8)	0.58 (0.45, 0.75)	<0.001
<i>Response cost</i>			
Low	149 (16.2)	1.00	
High	454 (40.1)	2.94 (2.30, 3.76)	<0.001

Multivariate logistic regression for psychosocial factors predicting the hesitancy to receive the COVID-19 vaccine.

^a OR was adjusted for age, education, occupation, family income per capita, proportion of vaccinated family members >12 years old, parents' self-assessment of children's overall health, and other PMT constructs.

level could modify the effect of coping appraisal, but not threat appraisal, on parental hesitancy. Based on our findings, parents who have higher levels of education are more likely to hesitate to vaccinate their children against COVID-19, and a high level of education can significantly increase the promotive effect of response cost and the protective effect of response efficacy on vaccine hesitancy. The educational level and the degree of reluctance to vaccination continues to be controversial. Previous studies have demonstrated the general argument that COVID-19 vaccine hesitancy rates are higher among parents with lower educational attainment [23–26]. For example, US parents who had a bachelor's degree or higher education had already received or were likely to receive a COVID-19 vaccine for their children [25,26]. In addition, the same phenomenon has been found among Italy parents/guardians of children aged <18 years old [23] and Canada parents of children aged ≤12 years old [24]. However, in other studies carried out in Saudi Arabia and Turkey, one of the factors associated with lower intention to vaccinate children was parents with higher education levels [27,28]. Here our team also identified a positive association between education level and vaccine hesitancy both among Chinese parents for their children's vaccination (this study) and among Chinese adults [8,16]. The possible explanation for our findings may be that parents with higher educational levels were more likely to have higher social status and therefore may have more channels to learn about the effects and side effects of vaccines. As we are discovering, the higher the education level of parents was, the greater the promotion effect of response cost assessment on vaccine hesitancy and the stronger the protective

effect of response efficacy assessment on vaccine hesitancy. These findings point out that interventions targeting response cost and efficacy are especially important for parents with high education levels to enhance the children's vaccination against to COVID-19.

As expected, coping appraisal, including response efficacy, response cost and self-efficacy, was crucial for predicting parental hesitancy about children's vaccination. In our study, response efficacy includes agreements about the contribution of children's vaccination to the prevention of COVID-19 infection, to the convenience of children's daily lives and travel, and to establishing immunity. To a certain extent, response efficacy can reflect parents' evaluation of the effectiveness of the vaccine, their hope to restore normal life and social life, and their perception of the externality and altruism of the vaccine. Consistent with our results, response efficacy was also identified as an important predictor of adults' willingness to vaccinate themselves against COVID-19 [29] and seasonal influenza [30] or parents' willingness to vaccinate their children against measles [31] and HPV [32]. When parents perceive higher response costs, such as concerns about side effects after vaccination and long-term adverse reactions, they are more likely to be vaccine hesitant, which is detrimental to the implementation of vaccine programs. Studies from China [33], Turkey [27] and a global study from six countries [34] all reported that concern about the safety and side effects of vaccination is one of the reasons why parents do not vaccinate their children against COVID-19. Except for awareness of vaccine safety and side effects, response cost also included concerns about the effectiveness of the vaccine. If parents believe that the vaccine cannot protect against the mutant strain, they believe it is useless to vaccinate their children. Lack of knowledge about vaccine effectiveness is one of the most common reasons for parents in Shanghai, China to refuse COVID-19 vaccination [35]. Vaccine effectiveness and safety have been reported to be important factors predicting parental COVID-19 vaccine hesitancy or vaccine willingness in children under 18 years of age [21,36–38], and here, we provide evidence about parental attitudes towards the COVID-19 vaccine for their children aged 6–12.

We also found that low perceived susceptibility was related to parental vaccine hesitancy, probably because perception of the risk of COVID-19 disease may affect parents' decision-making [5]. Moreover, low self-efficacy indicates an increased possibility of vaccine hesitancy. Several studies have shown that self-efficacy is a key factor affecting COVID-19 vaccination willingness and predicting adults' or parents' vaccination behaviour in China [8,16,17]. Studies of H1N1 vaccines also suggest that the public's self-efficacy of H1N1 vaccination can be boosted by increasing the benefits of vaccination [39]. In this study, severity was considered to have little to do with vaccine hesitancy, which is similar to the results of some studies [16,40], probably because parents will first consider whether their child is susceptible to an illness before considering how severe the illness may be [40].

Table 4
Correlations between COVID-19 vaccine hesitancy and parental education level and PMT constructs.

	1	2	3	4	5	6
1. vaccine hesitancy	–					
2. education level	0.172**	–				
PMT constructs						
3. perceived susceptibility	–0.222**	0.020	–			
4. perceived severity	–0.215**	–0.010	0.232**	–		
5. response efficacy	–0.428**	–0.121**	0.274**	0.433**	–	
6. self-efficacy	–0.279**	–0.075**	0.208**	0.302**	0.483**	–
7. response cost	0.262**	0.133**	–0.013	0.022	–0.175**	0.023

* $P < 0.05$.

** $P < 0.01$.

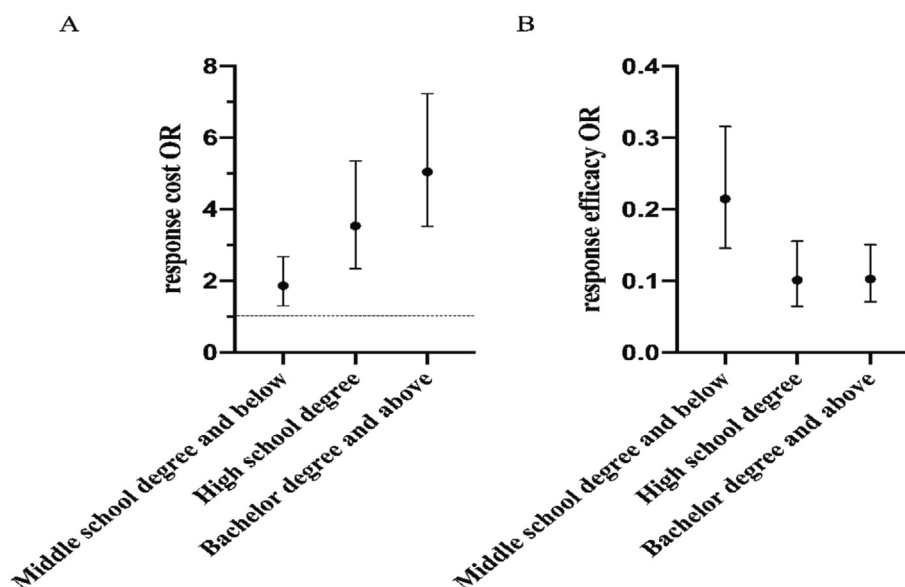


Fig. 1. Association between vaccine hesitancy and PMT constructs in CMH analyses.

Other demographic factors should also be noted. Young parents showed more COVID-19 vaccine hesitancy, which is consistent with another study in which the highest vaccine hesitancy rates were detected in parents ≤ 29 years old [23]. Parents who assess their children as unhealthy are more likely to hesitate to vaccinate their children against COVID-19, and the same situation was also found among adults [16]. In our study, health care workers showed higher vaccine hesitancy about children, which is consistent with previous findings that health care workers showed low acceptability of COVID-19 vaccination despite their important roles in vaccination promotion [33]. According to previous studies, there are three possible reasons. First, concerns about the expedited development of COVID-19 vaccines have led to vaccination hesitancy [41]. Second, they might be more aware that the risk of death caused by COVID-19 is low among children, and most infected children would not be symptomatic [42]. Third, health care workers have growing scepticism about the safety and effectiveness of COVID-19 vaccines [43,44]. In addition, the lower the proportion of vaccinated family members was, the stronger the parental vaccine hesitancy for children. The lower proportion of vaccinated family members may reflect a history of unwillingness to receive vaccines. A study from China Hong Kong found that parents' histories of receiving COVID-19 vaccines themselves were significantly related to parents' intentions [17]. It was also suggested that previous vaccination experience might have an impact on current willingness to vaccinate [5]. Considering the hysteresis for vaccination among children [45], the important role of children in transmitting COVID-19, and the side effects and efficacy of vaccines [46], health educators have been encouraging child vaccination to reduce school and community transmission. We suggest that health educators should focus on the knowledge about safety and efficacy of vaccines among parents with medium to high levels of education to reduce their concerns about vaccinating their children.

5. Limitations

There are several limitations of the present study that should be noted in interpreting the results. First, the sampling process of the online survey may result in selection bias. The survey link disseminated by WeChat can only reach network members, which limits

the generalizability of the results. Second, the assessment of parental hesitancy about children's vaccination occurred during a short time; thus, the results may not reflect the long-term effect of these identified influencing factors because the hesitancy to obtain the vaccine will decrease with the increase in the number of vaccinated children in the future. Third, the cross-sectional design conducted to measure the exposure and outcome of parental vaccine hesitancy simultaneously only measured the situation of a certain population at a certain point in time. Thus, causality cannot be proved; only possible factors for causality can be provided. As mentioned above, parental hesitancy about children's vaccination against COVID-19 may change as the pandemic evolves and more information about vaccines is released. Despite these limitations, our findings contribute insights into targeted interventions aimed at reducing parental hesitancy for children's vaccination.

6. Conclusion

Health education to parents is warranted when the COVID-19 vaccine is available and authorized for use in children. This study's findings suggested that the PMT model can be used to develop strategies for reducing parental hesitancy about children's vaccination. Interventions targeting response costs, i.e., worries about COVID-19 vaccine adverse reactions, short effective time of prevention and useless resistance to the mutant strain, are crucial. Similarly, interventions targeting response efficacy, i.e., agreements in the contribution of children's vaccination to the prevention of COVID-19 infection, convenience of children's daily travel and life and establishing children's immunity, are also important. Importantly, all of these interventions targeting response cost and efficacy are especially important for parents with high education levels. Perceived susceptibility could decrease parental hesitancy, which suggests that the government should publicize children's high risk of infection, emphasizing the current popularization of vaccination among adults and the lack of prevention awareness of children. Self-efficacy was negatively related to parental hesitancy, providing guidance for policy recommendations for enhancing education about vaccination knowledge for parents, such as vaccination locations and treatments of side effects.

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Data Availability Statement: The data that support the findings of this study are available from school of public health, Fudan University but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of school of public health, Fudan University.

Ethics approval and consent to participate: This study was approved by the Ethics Committee of Department of Public Health in Fudan University, Shanghai, China (IRB#2021-10-0932). All participants or their legally acceptable representatives provided written informed consent.

CRediT authorship contribution statement

Shuning Tang: Investigation, Data curation, Writing - original draft. **Xin Liu:** Investigation. **Yingnan Jia:** Investigation. **Hao Chen:** Investigation. **Pinpin Zheng:** Investigation, Writing - review & editing. **Hua Fu:** Writing - review & editing. **Qianyi Xiao:** Conceptualization, Investigation, Data curation, Writing - review & editing.

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.vaccine.2022.11.060>.

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